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STUDY OF AURORAL BREAKUP STRUCTURE AND CONJUGATE ENERGETIC ELECTRON INJECTION MEASURED BY THE CRRES ON FEBRUARY 13, 1991

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Abstract. CRRES energetic electron and proton measurements and auroral TV observations at Loparskaya observatory during moderate isolated substorm at 20-21 UT, February 13, 1991 are presented. The CRRES was at the apogee of orbit 494 in the outer radiation belt near the magnetic equator. CRRES footprint projection calculated using the Tsyganenko magnetic field model was located 4^0 east of Loparskaya during the breakup. It is shown that injected energetic electrons have been accelerated simultaneously with one of the auroral activations, approximately at the same latitude and within the same azimuthal region. The lack of enhanced electron flux during other (more poleward) activations suggests that the acceleration region has a sharp equatorial boundary.

Introduction

We present a case study of a moderate isolated magnetospheric substorm at 20-21 UT, February 13, 1991 when an aurora has been registered by the TV camera at Loparskaya observatory and energetic particle flux increase associated with this substorm has been registered on board of the CRRES satellite (mlat=-2.2^0 , 23 MLT, r=6.3Re).

Geometry of the magnetospheric substorm, especially the conjugacy of the auroral breakup and associated substorm onset instability in the magnetosphere are the key problems of substorm physics, and we will use this rare occasion of simultaneous observations for a detailed investigation of the fine 3-dim structure of the disturbance.

There are results which show that particle injection at the geostationary region correlates very well with some particular active aurora near the satellite footpoint [*Akasofu et al.*, 1974, *Kozelova et al.*, 1986, *Nakamura et al.*, 1991]. However there are numerous publications associating active aurora with more distant regions in the far magnetotail. Therefore any new data on geometry of the disturbed magnetosphere are important.

Auroral TV observations

Observatory Loparskaya of the Polar Geophysical Institute is situated inthe northen part of the Kola Peninsula (68.62N, 33.3E). Figure 1 shows the map of Kola Peninsula with field of view of the TV camera and calculated CRRES footprints at different time moments.

The disturbance was relatively weak, (-300nT) and fairly complicated. It consisted of several intensifications, separated in time and space with their individual auroral breakups and negative magnetic bays.

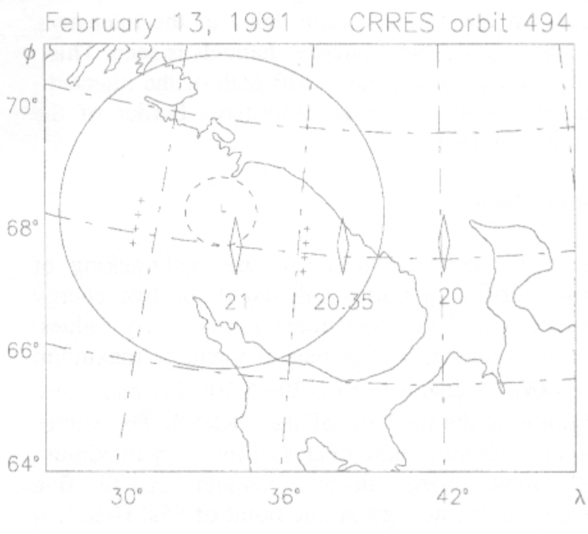


Figure 1. CRRES footprints and TV camera field of view. Crosses indicate the position of the calculated boundaries of the particle source region.

We will discuss here the second intensification, which was short, started at 20.32 and declined before 20.38 UT. This intensification developed in the form of three successive auroral activations. It was possible to observe a restricted poleward expansion in each activation, but the latitudinal position of the second and third activations moves steplike to the south. Figure 2 presents TV frames illustrating the shape and position of these activations.

Fine temporal and spatial structure of the breakup is illustrated in Figure 3, where artificial photometric records compiled from the TV data files are presented. The "photometers" are directed at different points in the sky along the Loparskaya meridian and present the auroral brightness at three different latitudes. On the bottom panel are presented the magnetic pulsations of the Pi2 type registered by Lovozero observatory. Three main activations which can be clearly distinguished on the original record are seen in this figure.

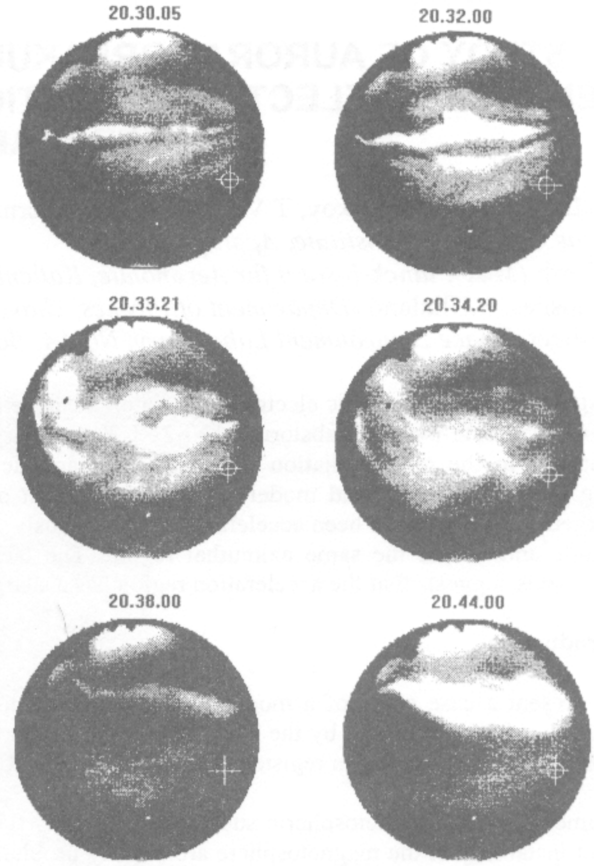
CRRES, energetic electrons

According to the energetic particle pitch angle distributions the CRRES was in the outer radiaton belt inside the trapping boundary. Energetic electron injection was registered by the CRRES in the middle of the second auroral intensification. The proton flux enhancement was absent suggesting that substorm active region was located westward of the satellite, which is in agreement with the footprint position calculated using the Tsyganenko [1989] model. Figure 1 shows the footprint position for three moments by diamonds, which are centred in accordance with results of the model option 3 (equal to the actual Kp=2) and have the size corresponding to the Tsyganenko-89 model options 2 and 4.

Figure 4 presents the electron differential flux data integrated over 2 seconds registered on all the pitch angles. In this figure a time delay of the intensity maximum in different energy channels is seen. This could be used to calculate drift path of the injected electrons from the distant (western) border of the acceleration region.

Comparison

Figure 5 shows the result of the backtracking of particle drift trajectories calculated for five energy channels based on experimental time delay values. Here the moment T=0 is that of intensity maximum in 100keV channel (T_0=20.35:10UT) and zero longitude is the position of the CRRES. The values T>0 correspond to time delays of intensity maximum in the lower energy electron channels. All the five velocity lines intersect in one point of 55s. Hence, it can be concluded that, 55s before the To, all electrons started off at the distance of 7.2^0 westward the CRRES (see Figure 1). An additional small correction of the calculated drift time is necessary, taking into account, that electrons registered by CRRES detectors started drifting with a smaller energy and therefore smaller drift velocity. That may change the delay time up to 65s. Thus, the acceleration source started working at ~ 20.34:05 UT.



13 Febr.1991. Loparskaya

Figure 2. TV all sky snapshots from Loparskaya for several moments before, during and after the second breakup. South is on the bottom and West at the left side of the pictures. The cross in a circle shows position of the CRRES footprint.

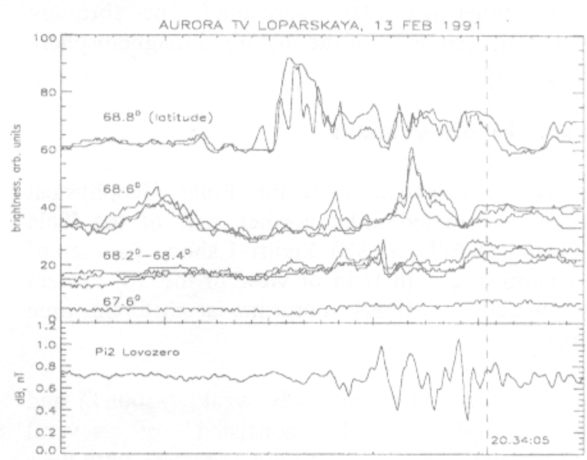


Figure 3. Synthetic photometer records at the Loparskaya meridian during three auroral activations. Two or three neighbouring points were used to show data deviation. The dotted line marks calculated starting time of the electron acceleration. Bottom panel presents magnetic Pi2 pulsations registered at Lovozero observatory.

This time is marked in Figure 3 by the vertical dotted line and it coincides with the third most equatorward auroral activation. No enhancement was observed in the electron flux in association with the first and second activations, which were most intense and located poleward. It is difficult to suppose that these activations did not generate energetic electrons. But if geometry of the energetic electron acceleration region was the same, as the position of the auroral activations, with a similar sharp equatorial boundary, then the electron clouds from the first two activations had to pass poleward of the CRRES in their magnetic drift.

Intensity enhancement begin in low energy channels long before the maximum, which means, that at the beginning we observed the arrival of electrons from smaller distances (from eastern border of the source region). From the time of the beginning of intensity increase in channels 2-3 we could find that these particles came from distance of ~2°. The azimuthal extension of the source region is ~ 6° and agrees approximately with third auroral activation region (see Fig.1-2).

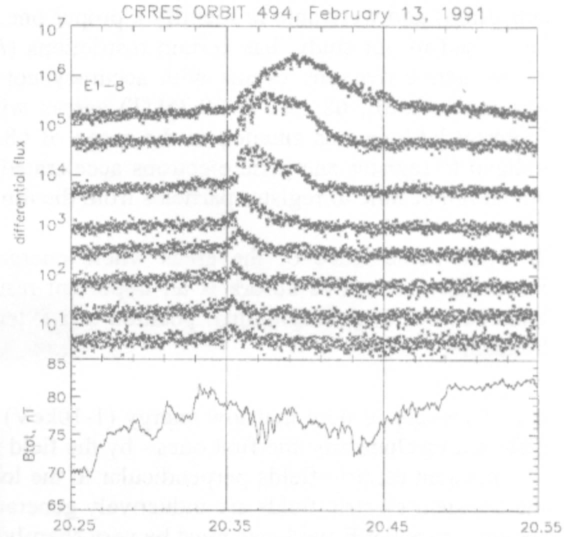


Figure 4. Energetic electron injection temporal structure with 2s resolution, channels 1 to 8 (energy ranges in keV are 21.5-31.5-40-49.5-59-69-81-94.5-112). Bottom panel presents :total magnetic field magnitude.

Discussion

During the substorm on February 13, 1991 two phenomena have been registered in the midnigth sector, i.e. Auroral intensification and energetic electron flux increase in the magnetosphere. Let survay the main experimental facts.

1. It has become popular to refer to any auroral intensification that are not a classical auroral breakup with a large poleward expansion as a "pseudobreakup". Possibly it is not a useful division. Expansion *par se* is not the main element of the substorm onset instability: it is rather a consequence. There are several types of auroral intensifications that belong to breakup events because they have most of the breakup features. Our auroral event is a good example of such of one. It started in the equatorial diffuse arc, being preceded by a short brightening of the arc and accompanied by magnetic Pi2 pulsations and negative h-bay registered by several ground-based magnetometers. As we know now, it was accompanied by the increase of energetic electron intensity in the magnetosphere. The only difference from classical breakup is absence of the noticeable poleward expansion. There was small poleward shift during each activations, but general direction of the activity propagation was equatorward, the same as during the growth phase. It is not a rare type of auroral intensification, especially in the middle of disturbance interval and near equatorial edge of the auroral substorm region.

Localized and short-lived (a timescale of ~1-2 min) auroral activations are a common feature of the substorm intensification. A similar fine structure is observed in energetic electron precipitations [*Melnikov et al.*,1978] and energetic particle variations in the magnetosphere[*Lazutin et al.*, 1998]. Our results suggest that the source region of the energetic electron injection is confined within region of auroral activation which in our case has the longitudinal range of ~5-6°. This doesn't supports the model of the injection boundary extending from dusk to down [*McIlwain*,1974]. Usually the electron intensity variations during injections are more complicated, compared to those observed in our study. Fortunately in our case only one activation was registered with the duration of the acceleration and rate of intensity increase typical for a single activation.

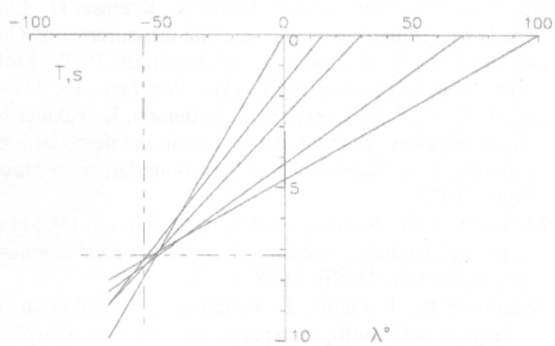


Figure 5. Calculated drift trajectories of the electrons of the channels 2, 3, 5, 6, 8. Latitudinal distance is in degrees, time is in seconds. T_o=20.35:10UT is the moment of intensity maximum in 100keV channel and λ° = 0 is the position of the CRRES.

2. For investigation of the conjunction it is important to have a good coincidence in time of the effects which are compared. Indeed, during several minutes of breakup, dynamical processes are usually registered in extensive magnetospheric main region from the inner boundary of the plasma sheet to the BLPS. Therefore, comparison of the processes separated in space with accuracy of 1-2 minutes does not provide grounds for reasonable conclusions.

In our case study we escaped this problem, because from the TV data we knew about three localized short-lived auroral activations and were able to identify a proper one. It is necessary to mention that the Tsyganenko-89 model, which we have used in our study, has certain restrictions (*Reeves et al.*, 1996). Statistical model can predict footprint position during active dynamic events with accuracy not better than 1 degree. But in our specific case calculated footprint position (37.55E, 68.25N at 20.35UT) agrees with the experimental results. From experiment we can estimate that footprint latitude was situated in the range of 68.1-68.6N. If the footprint of the satellite was poleward, it would be obliged to register energetic electrons accelerated in the second activation. If it were located to the south, it possibly would not be able to register particles from the third activation.

3. Good coincidence of the areas where energetic electrons are accelerated with those for low energy electrons responsible for active aurora is an important result of this study. We can not claim that these areas are completely identical, but their longitudinal position and extension are similar and they both have a sharp southward (Earthward) boundary.

It is necessary to note that low energy (1-10keV) auroral particles and energetic ones (20-500keV) are accelerated by different mechanisms: the first ones - by the field aligned component of the electric field, whereas the second ones - by the transient electric fields perpendicular to the local magnetic field. Calculations by *Aggson et al.* [1983] indicate that the transient electric fields are inductively generated in a spatially confined region. Our analysis shows that the source region where the E field acts must be very sharply restricted on the Earthward side.

Magnetic field configuration and trapped particle distribution strongly suggest that the described event takes place in the inner magnetosphere (radiation belt) and hence the reconnection model of substorm is less acceptable than that of current disruption [*Lui et al.*, 1988, 1992] or ballooning instability [*Samson et al.*,1996]. Geometry of the current disruption must be more complicated than a single current wedge and must result in localized particle acceleration region. Possibly it is necessary to return to the magnetotail current meander model suggested by *Heikkila and Pellinen* [1977], *Pellinen and Heikkila*, [1984], but applied to the radiation belt region.

Conclusion

It is shown, that in the case observed on February 13,1991 the energetic electron source region was conjugated with localized auroral activation and had a sharp Earthward boundary.

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